Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendments of Parts 2 and 15	)	ET Docket No. 94-124
of the Commission's Rules to Permit	)	
Use of Radio Frequencies Above 40 GHz	)	RM-8308
for New Radio Applications	)	
	)	

<u>Comments of Hewlett-Packard Co.</u>
In Support of Proposed Rulemaking for Frequencies Above 40 GHz

Introduction

1. HP Supports the Millimeter Wave Proposal

We commend The Federal Communications Commission and its staff for inviting industry and the public to help create a well-considered U.S. millimeter wave policy that will have positive benefits for all. We agree completely with the philosophy of the Notice of Proposed Rulemaking [NPRM] as expressed in paragraphs 1 - 6. We point out that the millimeter wave frequency band is a valuable resource capable of providing unique and useful services in the public interest. Advance planning can enable wise development of this resource, and all points of view should be considered. In these comments, we respond to several of the questions posed in the NPRM and we propose some changes to the original plan. We applaud the balance between licensed and unlicensed services as proposed by The Commission, and offer to help develop a spectrum etiquette for unlicensed millimeter wave communications. We urge swift action to set aside large blocks of contiguous bandwidth for high speed communications, particularly in the 56 - 64 GHz band. We support unlicensed operation of automotive radar, but only in bands specifically set aside for the purpose. We support the proposal for licensed services in the 40.5 - 42.5 GHz band, and call for additional licensed and unlicensed bands below 100 GHz. We recommend delaying rules for most frequency bands above 100 GHz, and offer a revised spectrum plan for services below 100 GHz.

2. We See Potential Economic Benefits

Hewlett-Packard has a long history as a manufacturer of microwave and millimeter wave test equipment, but our interests in the millimeter wave area go well beyond test and measurement. We, and many of our U.S. competitors, are now heavily involved in the Information Technology business. This business is a key contributor to U.S. exports, and a key provider of American jobs. By the year 2000, we expect that 70% of the demand for information technology will come from outside the U.S., up from the present 62%. Right now, 88% of R&D jobs in the U.S. computer industry, and 70% of its manufacturing jobs are within the U.S.[1] If we want to maintain this

1. Source: Hewlett-Packard Company, Corporate Communications Department..

growth in exports while at the same time avoiding the export of jobs, we must capitalize on one of this country's main strengths: technical innovation. One field of U. S. technical excellence is millimeter wave technology, and although work in this field has been directed mostly toward military applications in the past, the technology has advanced to a point where commercial applications may be feasible. If technology costs can be reduced, two major information industry trends - wireless interconnects and high bandwidth data delivery - could be addressed by high-bandwidth millimeter wave technology. As are other U.S. companies, HP is investing R&D effort toward these goals. Government regulatory agencies have a key role to play here. Without regulatory permission, nothing can happen. Without regulatory protection and stability, private industry will not risk the investment required to develop commercial products and create jobs. Also, it should be pointed out, international coordination of regulatory efforts is mandatory from the point of view of American companies that wish to produce products for sale abroad. We hope that the proposals synthesized during the comment period will be given a thorough review for international compatibility, so that our radio regulations do not become *de facto* trade barriers.

Proposed Frequency Bands

3. We Support the Proposed 40.5 - 42.5 GHz Licensed Band

We strongly support the establishment of 40.5-42.5 GHz as a licensed band for LMWS. The increased territory size [MTA] and removal of buildout and subdivision restrictions are a positive step toward creating a competitive environment for provision of broadband multipoint distribution, or other appropriate services. We also point out that the European trend toward using this band for video distribution[2] creates an opportunity for an international market for U.S.-manufactured equipment which might be developed for the domestic 40.5-42.5 GHz service. We further note that one of the chief advantages for millimeter wave transmission is the inherently high bandwidth capability it affords. By setting aside 1 GHz for each of two license holders in an area, The Commission has provided contiguous bandwidth roughly equal to that available with coaxial cable, thereby enabling wireless transmission of broadband services.

4. Larger Areas, No Buildout Requirements & Longer License Terms are Better

We very much favor use of Major Trading Areas rather than Basic Trading Areas for licensing purposes. This gives the licensee far more flexibility in designing a network and provides greater incentive to make the investments required to take full advantage of millimeter wave technology. It also minimizes the boundaries across which standard protocols and interference levels would have to be addressed. We agree with The Commission's proposal to go to a 10 year license term. In developing renewal expectancy rules we propose that the investment made by the licensee over the 10 year license period should be the major criterion for judging whether or not the licensee has conscientiously pursued the utilization of the license. We feel that the buildout requirements originally proposed for the 28 GHz band were impractical, since provision of millimeter wave service to many subscribers would be impossible, due to lack of line-of-sight or near-line-of-sight access, and the number of such cases would be difficult to predict. The public interest is best served by making service available to subscribers using the most practical delivery means available. We envision geographical areas in which a hybrid approach would be used to deliver services. Some subscribers would be serviced by millimeter wave links, some by coaxial cable and still others by

2. See: CEPT Recommendation 52-01

fiber. The choice would be made on the basis of technical and economic considerations, and the public interest would be better served than with specific buildout requirements.

5. We Propose Modifications to the Frequency Plan

While we strongly support the NPRM frequency plan in most respects, we offer some modifications and the rationale for them. Our modified proposal is outlined below, and compared to the original plan in Table 1 and Figure 1. Details are given in paragraphs that follow.

Table 1: Frequency Plan Comparison

Frequency Band	NPRM Proposal	HP Proposal
40.5 - 42.5 GHz	2 Licensed Bands	2 Licensed Bands
47.2 - 47.4 GHz	Vehicular Radar	Vehicular Radar
47.4 - 48.2 GHz	2 Licensed Bands	General Unlicensed Band
48.2 - 50.2 GHz	None	2 Licensed Bands
56 - 58.2 GHz	None	Multiple Licensed Bands
59 - 64 GHz	General Unlicensed Band	General Unlicensed Band
71 - 72 GHz	Half licensed/Half unlicensed	General Unlicensed Band
76 - 77 GHz	Vehicular Radar	Vehicular Radar
84 - 85 GHz	Half licensed/Half unlicensed	General Unlicensed
94.7 - 95.7 GHz	Vehicular Radar	Vehicular Radar
103 - 104 GHz	Half licensed/Half unlicensed	Experimental Licenses Only
116 - 117 GHz	Half licensed/Half unlicensed	Experimental Licenses Only
122 - 123 GHz	Half licensed/Half unlicensed	Experimental Licenses Only
126 - 127 GHz	Half licensed/Half unlicensed	Experimental Licenses Only
139 - 140 GHz	Vehicular Radar	Vehicular Radar
152 - 153 GHz	Half licensed/Half unlicensed	Experimental Licenses Only

	NPRM Proposal	HP Proposal
	Vehicular Radar: 3.2 GHz	Vehicular Radar: 3.2 GHz
	Licensed Spectrum: 6.3 GHz	Licensed Spectrum: 6.2 GHz
	Unlicensed Spectrum: 8.5 GHz	Unlicensed Spectrum: 7.8 GHz
	Total: 18 GHz	Total: 17.2 GHz

Comparison of Proposals, 40 - 100 GHz:

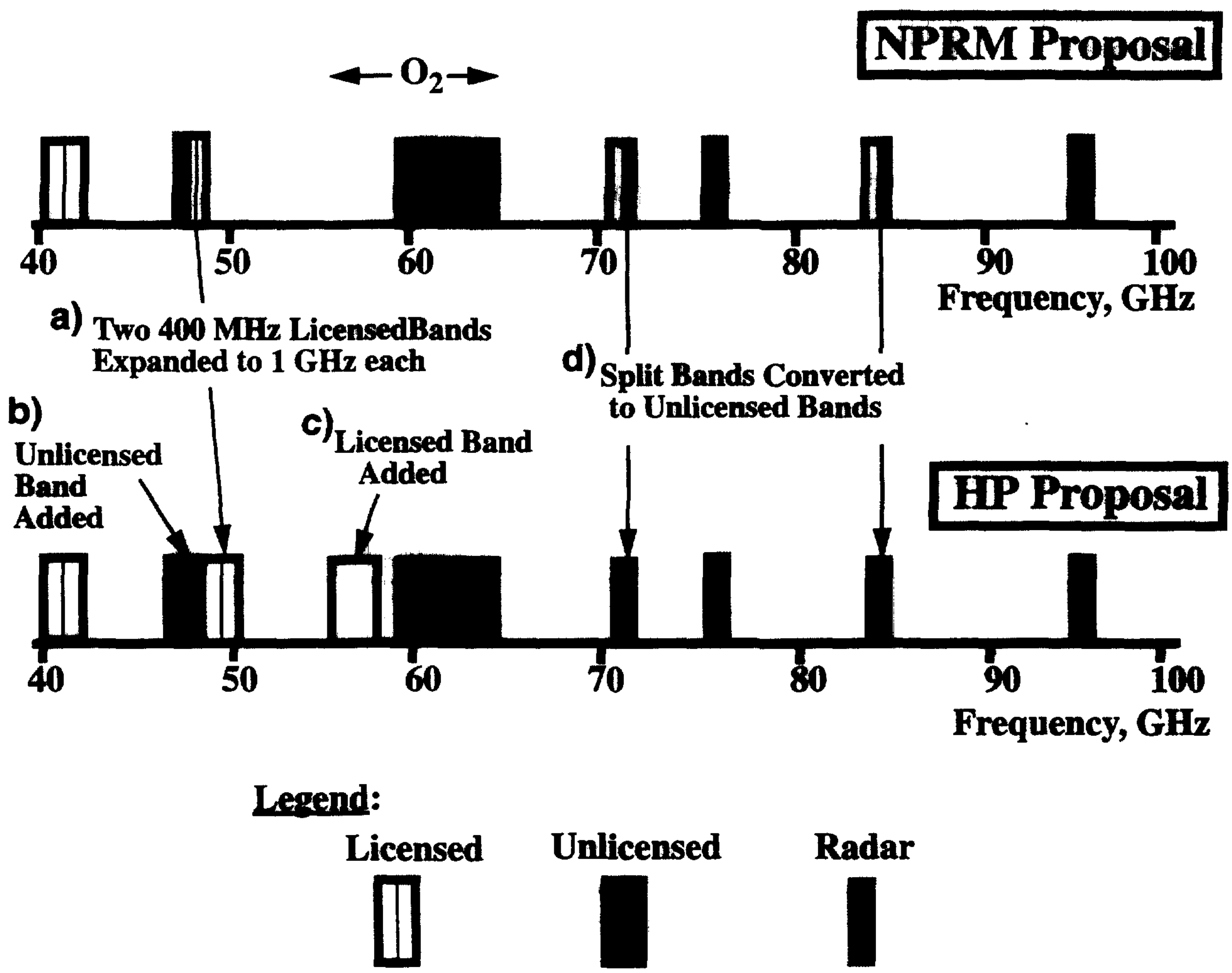


Figure 1: We propose modifying the band assignments below 100 GHz as shown above: a) two 400 MHz licensed bands are expanded to 1 GHz apiece and slightly relocated; b) 800 MHz of general unlicensed spectrum is added between the radar and licensed bands; c) 2.2 GHz of licensed spectrum is added to the oxygen absorption band (detailed assignments to be determined by future action); d) two licensed/unlicensed bands (with only 250 MHz per license holder) are converted to unlicensed bands. With the exception of the 139-140 GHz vehicle radar band, no licensed or general unlicensed assignments would be made above 100 GHz at this time. Overall, the total bandwidth is reduced from 18 GHz to 17.2 GHz and licensed spectrum increases from 35% to 36% of the total, with more of it assigned to lower frequencies.

6. Proposed Changes for Bands Below 50 GHz

We strongly urge the commission to consider another assignment of at least 2 GHz of spectrum in the 40 - 50 GHz band. The band 47.2- 50.2 GHz which is currently designated, both in the U.S. and internationally, for Fixed, Fixed Satellite (earth to space) and Mobile, would be a good candidate for assignment. The NPRM proposal breaks up this band, assigning 47.2 - 47.4 GHz to Vehicular Radar and 47.4 - 48.2 GHz for LMWS. The remainder of the band, 48.2 - 50.2 GHz was not discussed in the NPRM. This band could, for example, be used for point to point links between locations where it is not economical to interconnect with fiber. It would also provide for future growth in the need for delivery of broadband services in a frequency band that can be economically addressed with solid state technology that is now, or soon will be, available. We therefore propose the following for the 47.2 - 50.2 Band:

Table 2: Band Proposal, 47.2 - 50.2 GHz

Frequency Band	NPRM Proposal	Our Proposal
47.2 -47.4 GHz	Unlicensed Vehicular Radar	Unlicensed Vehicular Radar
47.4 - 48.2 GHz	2 Licensed Bands, 400 MHz each	General Unlicensed Band
48.2 - 50.2 GHz	None	2 Licensed Bands, 1 GHz each

7. We Propose a Licensed Band 56 - 58.2 GHz

The NPRM establishes licensed bands below the oxygen absorption band [56-64 GHz] and sets aside 63% of the O_2 band for unlicensed use [59-64 GHz]. We strongly support this decision, but point out that there may well be, in future, applications which require both the attenuation characteristics of the O_2 band and the absolute protection from interference that licensing affords. Such an application could be for short range point-to-point broadband links, where the ability to re-use a frequency on a distance scale of ~1 km could be extremely desirable and spectrally efficient. In anticipation of such demand, we recommend the establishment of a licensed band 56 - 58.2 GHz, the lower frequency being set by the O_2 absorption band edge, and the upper limit being set by the edge of the 58.2 - 59 GHz band. This would have the advantage of establishing a home for licensed applications, with the coordinated benefit of relieving possible future pressure to cannibalize the 59-64 GHz unlicensed band. We have made enquiries through the NTIA'a Spectrum Openness Program about possible government concerns over the use of this band. The response was as follows: "I have not found any Federal Agency plans that would likely conflict with your proposed use of the 56-58.2 GHz band".[3]

8. No Ground - Satellite Interference Can Occur in the 56-64 GHz Band

The Commission has requested [NPRM, footnote 18] "...detailed analysis and comment on whether terrestrial use of the 60.4-61.2 GHz band would interfere with NOAA's planned opera-

3. E-mail response 12 September, 1994 from Norbert Schroeder, Director, Spectrum Openness program, U.S. Department of Commerce, NTIA.

tions". Our detailed analysis [Appendix A] indicates that it will not be possible for the proposed unlicensed devices in this band to interfere with satellites. We further note that the *Space Frequency Coordination Group,* an international body representing the interests of the passive spaceborne microwave sensor community, has concluded that: "*...studies have shown that sharing with terrestrial services is practicable at frequencies above 56 GHz by taking advantage of high atmospheric absorption*". This body goes further, recommending: "*...that member agencies inform their administrations that, taking advantage of the atmospheric absorption in this band, the passive sensing allocation in the 58.2 - 59 GHz [band] can be shared with Fixed and Mobile Services*".[4] Since 58.2 - 59 GHz is presently a band in which, by international agreement, no transmissions are allowed, this resolution could presage a lifting of the international prohibition on transmissions in this band, a trend The Commission may wish to note. Future expansion of the proposed Licensed O_2 Band may be possible if, and when, the 58.2-59 GHz band transmit restriction is lifted.

9. We Support Exclusive Bands for Unlicensed Vehicular Radar

We strongly agree with The Commission's proposal to allow vehicular radars to operate on an unlicensed basis in bands set aside for their exclusive use. Sharing with licensed services would seem impractical. We feel that it will be absolutely essential to limit vehicular radars to their assigned bands. These devices must operate continuously to be effective, and can not be subject to interference from unlicensed devices of other types, since unacceptable safety hazards could result. Vehicular radars would also have great capacity to do harm to the integrity of communications in the general unlicensed bands. Therefore, as a vital issue of public interest, The Commission's rules must make it clear that no vehicular radars will be allowed in the general unlicensed bands.

10. Bands Should Provide At least 1 GHz of Contiguous Spectrum

We support the band-splitting approach used in LMDS as a way of ensuring competition in a given geographical area. However, we need to emphasize the point that perhaps the chief advantage of millimeter waves over lower frequencies is the large bandwidth available as a small percentage of the carrier frequency. We feel the 1 GHz per license holder, or group of unlicensed users, is the minimum that should be considered in the millimeter wave bands. In the bands above 64 GHz, with the exception of the proposed Vehicular Radar allocations, The Commission has elected to limit the bands to 1 GHz. These bands are then divided between licensed and unlicensed users into 500 MHz bands. If licensed applications are further divided between two licensees in a given geographical area, there would be only 250 MHz per licensee. Given the limitations of practical components, use of these bands would further be limited by the need to include some guard band to minimize out-of-band emissions. We feel that this proposed bandwidth assignment will not allow manufacturers to take full advantage of the potential for the millimeter wave spectrum as a means for delivering broadband services. The Commission has already pointed out (NPRM Paragraph 8, footnote 12) that "...transmission of data rates ranging from 50 Megabits/second up to 5,000 Megabits/second, or more, are possible depending on the frequency band". The proposed allocation scheme would not come close to allowing that eventuality. It would be far preferable, in our opinion, to designate bands that would have the potential for providing each licensee, or community of unlicensed users, with a minimum of 1 GHz of contiguous spectrum.

4. Resolution 14-4 [22 September, 1994] of the Space Frequency Coordination Group.

11. Rulemaking for Most Bands Above 100 GHz Should be Postponed

There is a sort of technological divide centered roughly at 100 GHz. Below this frequency, Monolithic Microwave Integrated Circuits [MMICs] based on submicron-gate III-V material FETs are practical and available. Above this frequency, devices are much less general-purpose and hardware is consequently much more expensive. While we applaud The Commission's willingness to organize bands above 100 GHz, it may be that this is not yet the critical moment. With the exception of Vehicular Radar, for which there has been a specific request, we would propose that The Commission NOT adopt a band plan at present for frequencies >100 GHz, but rather encourage the issuance of experimental licenses for all the proposed bands. The decision about licensed-vs-unlicensed assignment could be left for a future date, when the applications picture will have become clearer.[5] We encourage The Commission to be liberal in its granting of experimental licenses in the >100 GHz frequency range, allowing very broad contiguous bandwidths as an incentive for experimentation in this technically difficult frequency range.

Other Spectrum Issues

12. No Band Sharing between Licensed & Unlicensed Devices

We strongly agree that Licensed and Unlicensed devices should not share bands.

13. Sharing Spectrum with Government

We believe that the vast majority of government millimeter wave applications can best be provided through use of commercial equipment and services, and that many government agencies will voluntarily look to the private sector for such technology and services. We urge The Commission to proceed immediately with rules for the millimeter wave bands, and believe that the public interest - both government and non-government - will best be served by such action. However, any auction proceedings which may occur for these bands would need to include full disclosure of possible government use or interference to potential bidders.

14. Registration of Unlicensed Installations

We believe that the public interest would be well served by a central national registry of unlicensed millimeter wave installations. Such a registry would help Part 15 users to plan their installations and to negotiate spectrum sharing when necessary. Such a registry could be kept by The Commission, or by private firms specializing in registration of licensed installations.

5. By suggesting that >100 GHz rules for services other than vehicular radar be put off to a future date, we do not wish encourage any delay in the setting of rules for the <100 GHz spectrum.

Proposed Technical Standards and Equipment Authorization

Licensed Devices

15. Licensed Services Power Limits [Ref: NPRM Paragraph 33]
We feel that the 16 dBW Equivalent Isotropically Radiated Power (EIRP), while a good number for most cases, would be too restrictive for some licensed services. Solid state devices are available today that will provide powers of close to 1 watt at 40 GHz. The power capability will increase over the next few years. Therefore, demands for higher EIRP are likely to develop. Point-to-point links with high gain, highly directional antennas could easily push toward 40 dBW EIRP. Therefore, we feel The Commission must be willing to allow higher power limits (on a case-by-case basis subject to coordination with affected licensees and safeguards against the possibility of human exposure). We recommend 40 dBW as a practical limit. However, for Licensed Services in the oxygen absorption band, where range limitation is the whole point, we feel the 16 dBW should be an absolute EIRP limit. Power density limits should be set at the boundaries of licensed service areas to minimize the potential for interference between licensees in adjoining areas. We would recommend a power density of less than 10 nanowatts/square cm with the flexibility to exceed the limit on a case by case basis, subject to coordination with license holders in the adjoining areas. Human safety interlocks could be a good approach for pole-mounted licensed transmitters, if the power density near the transmitter exceeds IEEE C95.1-1991 standards.

16. Licensed Services Spurious Emission Limits [Ref: NPRM Paragraphs 34, 41]
We recommend that frequency stability requirements be set such that the carrier frequency does not drift out of the assigned band and that the same temperature range requirements be used for licensed and unlicensed equipment. We recommend that out-of-band spurious responses for licensed transmitters be set to 50 dB below the +16 dBW average EIRP limit, that is, Spurious EIRP = -34 dBW. [See also: Paragraphs 20, 21]

Unlicensed Devices

17. Two Reasons for Power Limits in Unlicensed Devices [Ref: NPRM Paragraph 38]
There are two reasons to limit the power transmitted from unlicensed devices: (a) ensuring compliance with safety standards and (b) limiting the range over which transmitters could interfere with one another. The Commission proposes a single power measurement during type certification to control both these aspects. We strongly urge that separate measurements be made for (a) *safety limits* and (b) *range limitation*. [See Appendix C for technical discussion of measurements]. Below, we discuss separately the *safety limits* and *range limitation* standards.

18. Unlicensed Range Limitation [Ref: NPRM Paragraph 38]
In unlicensed services, the public interest is best served by placing mandatory limits on the power allowed to be transmitted, so as to minimize the probability of interference between users.
A. We recommend that unlicensed devices be specified in exactly the same manner as has been recommended for licensed devices: on the basis of Equivalent Isotropically Radiated Power [EIRP]. This specification is directly relatable to range and re-use distance, is unambiguous, and can be directly measured. We point out that the proposed method, i.e. measuring power density 3 meters from a radiator, could lead to ambiguous results, depending on whether 3 meters is in the near-field or far-field region of the radiator in question [See Appendix C]. We therefore propose

that, to derive the true EIRP, power should be measured in the far-field region, or that appropriate corrections [based on antenna pattern measurements] should be applied to near-field measurements. **Important note:** near-field measurements could allow extremely high EIRP transmitters to meet specifications, even though they were capable of extremely long range and could cause severe interference.

B. We recommend a maximum EIRP of +10 dBW for general unlicensed devices in the 59-64 GHz band, where oxygen absorption will limit interference [See Appendix B for technical discussion].

C. We recommend that, for regulatory purposes, power should be specified as the average power per radiator, as would be measured by an average-responding detector. If measured with a frequency-selective instrument, power should be defined as the sum of all frequency components radiated within the legal band.

D. Power limitation may not be sufficient to cover all cases of interference. Therefore, special protection may be required in the form of mandated features for all unlicensed equipment. For example, in Part 15.214 of its rules, The Commission recognized the need to protect the public switched telephone network from unintentional access, and mandated that each cordless telephone "...shall incorporate circuitry which makes use of a digital security code...". In Part 15.321 and 15.323 of its rules, The Commission had adopted detailed "spectrum etiquette" for unlicensed devices, with the objective of ensuring the best possible service to the public. We believe that some relatively simple system could be designed in which "smart" unlicensed millimeter wave transmitters could avoid interference by adopting some listen-before-talk etiquette. We further believe that industry groups have in the past been able to formulate spectum etiquette plans acceptable to The Commission. We plan to organize such a spectrum etiquette group for unlicensed millimeter wave devices, and to bring its recommendations to the attention of The Commission.

E. Unlicensed transmitters capable of being combined with other similar transmitters to form a phased array should be specifically prohibited, since such operation could synthesize radiators with EIRP in excess of legal limits, even though the individual transmitters were within legal limits.

19. Unlicensed Safety Standards [Ref: NPRM Paragraphs 39 - 40]

For unlicensed devices, we feel that the IEEE C95.1-1991 standard is reasonable, and will not be a constraining factor in the design of Part 15 transmitters. We further recommend that The Commission not allow active interlocks on Part 15 transmitters as a means of enabling radiated power in excess of health limits. Rather, The Commission should require that all devices comply with the safety standard at 2 cm from the boundary between the "device" and free space.[6] This solution would be fail-safe, tamper-proof, and in the public's best interest.

20. Unlicensed Device Spurious Emissions [Ref: NPRM Paragraphs 41 and 45]:

A. Three types of interference are contemplated for unlicensed devices: (a) self-interference due, for example, to multipath echos; (b) interference from unlicensed devices operating in the same band; (c) interference from devices outside the unlicensed band, due to their spurious emissions. Multipath interference (a) is clearly not a regulatory issue. Same-type interference (b) is probably

---

6. The "Boundary" would, for example, be the surface of a device's package - including a radome, or safety shield, if one is used.

the most serious threat, because unlicensed devices can be mobile, and could in principle operate legally very near one another. This case can, and should, be covered with a "spectrum etiquette" approach [see comments: paragraph 18D, above]. Out-of-band interference (c), though probably rare, is potentially a threat - one which The Commission should address through its Type Certification process. Since "spectrum etiquette" is clearly ineffective against out-of-band transmitters, the only recourse would be to extend the existing type certification spurious emissions testing for Part 2 and Part 15 devices into the > 40 GHz range. Even this testing may not prevent the worst-case scenario, i.e. when a mobile unit with legal out-of-band emissions is moved close to an unprotected Part 15 device operating in a band where the mobile unit's out-of-band emissions occur. However, by placing limits on these emissions during type certification, The Commission will serve the public interest by minimizing the probability of such occurences.[7]

B. We propose that The Commission extend its existing harmonic emissions limits for all devices with fundamental frequency equal to or greater than 10 GHz [previously tested to 40 GHz] to an upper frequency limit of 110 GHz. [See Appendix C].

C. As to spurious, harmonic, and subharmonic emissions from devices operating at a fundamental frequency above 40 GHz, we suggest that since no services are being proposed for frequencies above 170 GHz at this time, and since 170 GHz marks the edge of a standard waveguide band [Appendix C], that 170 GHz - instead of 200 GHz - be adopted as the upper limit for harmonic testing of devices operating above 40 GHz. Furthermore, should The Commission elect to delay rules for non-radar devices above 100 GHz, there should be no immediate need for testing above 100 GHz, since, as far as we know, vehicular radars [the only devices operating above 100 GHz] will not be sensitive to low level out-of-band interference.

D. Since in most cases the proposed bands are not contiguous, there is much lower probability of interference between adjacent bands in the millimeter wave spectrum than between adjacent bands at lower frequencies, where packing is tighter. The one notable exception in The Commission's proposal is the juxtaposition of the 47.2 GHz - 47.4 GHz Vehicle Radar Band with the 47.4 GHz - 48.2 GHz licensed band. Since auto radars are mobile and have the highest allowed EIRP [~+16 dBW] close-in spurious emissions from them could conceivably interfere with licensed receivers. We point out that one advantage of the modified spectrum plan [Table 1] is that the licensed band is no longer adjacent to the radar band at 47.2-47.4 GHz.

E. Per the discussion in Appendix B, we recommend that out-of-band spurious emissions for all unlicensed devices be limited to 50 dB below the +16 dBW vehicular radar EIRP limit, that is, Spurious EIRP = -34 dBW for all unlicensed devices. [See also: Paragraph 21]

---

7. We note that in Part 15.245 of its rules, The Commission limits harmonic emissions from 24.075-25.175 GHz unlicensed "field disturbance sensors" to 40dB below those devices' fundamental emission limits. In this case, the fundamental EIRP appears to be about 1 W, so that its second harmonic, which could fall within the proposed 47.4 - 48.2 GHz licensed band would be limited to about -10dBm. However, such a harmonic could conceivably cause interference with a licensed device at 48.2 GHz, so attention to the matter is surely warranted. In this case, we assume a transmitter at 24.1 GHz emits -10 dBm EIRP at 48.2 GHz, which is legal. If the 24.1 GHz transmitter were located 10 m away from a licensed 48.2 GHz receiver with a 10 dB antenna gain, that receiver would see the harmonic interfering signal at a level of -87 dBm, a level which could conceivably cause interference.

21. Summary of Proposed Transmitted and Spurious Power Limits
The following table summarizes the transmitted and spurious power limits we recommend for Unlicensed, Radar, and Licensed devices:

Table 3: Summary of Recommended Power Limits

	General Unlicensed	Unlicensed Radar	Licensed
Average EIRP	+10 dBW	+16 dBW	+16 dBW[a]
Out-of-Band Spurious Average EIRP	-34 dBW	-34 dBW	-34 dBW

a. Except for in the 56-59 GHz band, this power may be increased to +40dBW in special cases. However, spurious emissions would remain at -34 dBW.

Notes:
1. EIRP derived from far-field measurement or equivalent.
2. Peak power limited to 10 times the average power.

22. Unlicensed Susceptibility Standards [Ref: NPRM Paragraph 42]:
Although Part 15 devices must accept interference received, and in the past, poorly-designed consumer equipment has run afoul of high-power radar transmitters due to poor receiver selectivity, there exists an opportunity in the new millimeter wave unlicensed bands to prevent such occurences. Since there are neither government nor non-government transmissions presently operating in these bands, and since large amounts of spectrum is available, we propose that new high-power transmitters - government or non-government - be located outside unlicensed bands, and that the out-of-band spurious emission requirements be the same for government transmitters as for non-government transmitters. Poorly-designed receivers that can not tolerate reasonable interference - for example, those with poor selectivity - will fail in the market, in favor of better-designed gear. There is no reason for The Commission to require susceptibility specifications for unlicensed equipment until such time as a problem may develop.

Summary

23. Here are the main points of our comments:

1. We support the goals of the NPRM and applaud its balance between licensed and unlicensed services [Paragraph 1].
2. We strongly support establishment of a 40.5 - 42.5 GHz licensed band [Paragraph 3].
3. We propose detailed changes to the <100 GHz spectrum plan [Paragraphs 5-7; Table 1].
4. We note that the O_2 band is free from interference with satellites [Paragraph 8].
5. We strongly support unlicensed vehicular radar bands and point out that <u>radars must be restricted to the assigned bands</u> [Paragraph 9].
6. We propose that, with the exception of the requested >100 GHzvehicular radar band, it may be too early to establish use rules for frequencies above 100 GHz [Paragraph 11].
7. We strongly support the larger service areas and longer license terms, as compared to the 28 GHz LMDS proposal. We support the removal of buildout and transfer restrictions for licensed bands [Paragraphs 3-4].

8. We believe government and civilian users can share the millimeter wave spectrum, and that government pre-emption of spectrum is unnecessary. We urge moving ahead with rules for millimeter wave bands subject to government sharing [Paragraph 13].
9. We propose a flexible approach to setting power limits for licensed installations [Paragraph 15].
10. We propose limits on carrier power density and limits on spurious emissions for both licensed and unlicensed devices [Paragraphs 16, 20, 21].
11. We call for an EIRP limit of +10 dBW for general unlicensed devices in the 59 - 64 GHz band [Paragraph 18B].
12. We recommend near-field power measurements for health standards compliance, and far-field measurements for range limitation. For unlicensed devices, we feel that the IEEE C95.1-1991 standard is reasonable, and will not be a constraining factor in the design of Part 15 transmitters[Paragraph 19].
13. We recommend a spectrum etiquette approach for interference limitation between unlicensed devices, and propose to organize a group to develop such an etiquette. [Paragraph 18D].
14. We recommend that a national registry of unlicensed millimeter wave installations be established [Paragraph 14].
15. We recommend against mandatory susceptibility limits for Part 15 devices [Paragraph 22].
16. We provide technical appendices on satellite interference, power limitation in the O_2 band, and on millimeter wave measurements.

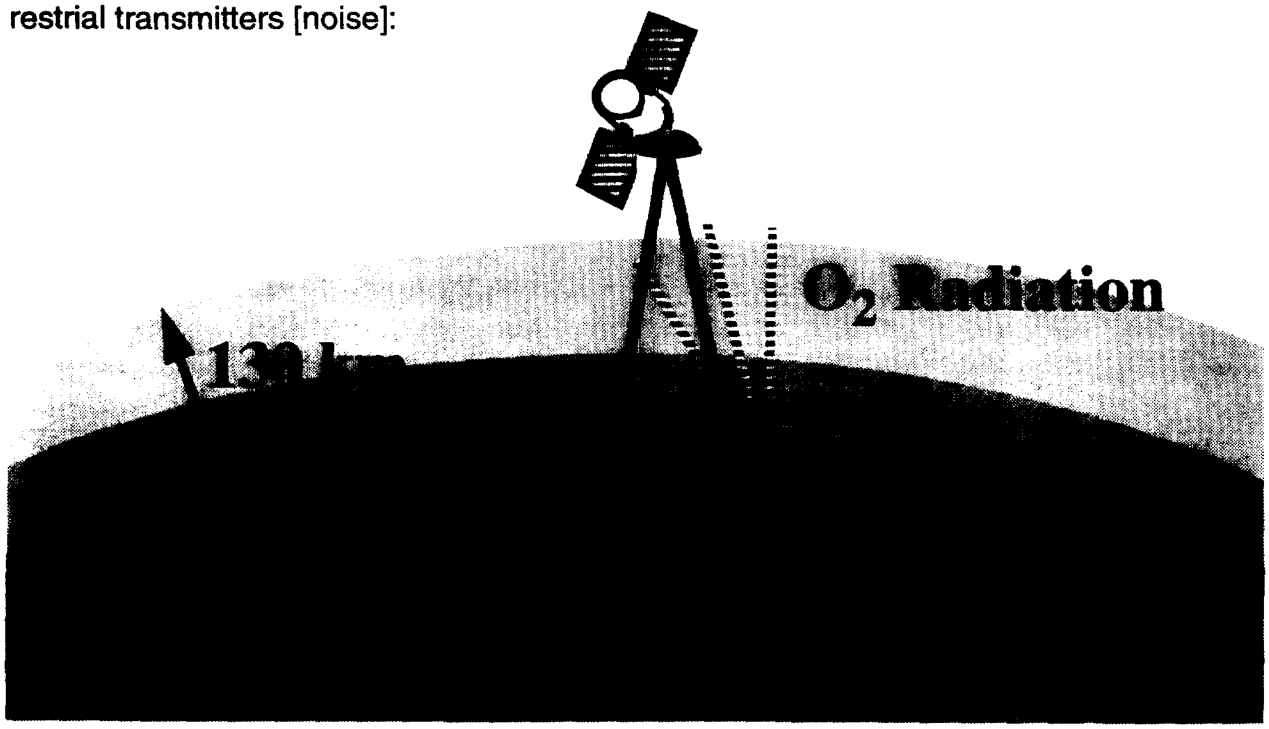
We appreciate the opportunity to comment on this important matter.

Appendix A:

Why Interference With Satellites is Not a Problem at 60.4-61.2 GHz

Background:
The U.S. Air Force plans to operate a polar orbiting satellite in the 1995-2000 time period whose purpose will be to measure temperature of the upper atmosphere by monitoring emissions from oxygen. This satellite, known as "DMSP" will orbit at an altitude of 833 km, looking with a 6° beamwidth antenna.[1] The satellite will measure emissions between 60.43478 GHz and 61.15056 GHz, where there are "...strong quantum states that permit temperature measurements without the strong influence of water vapor (clouds) found at the other O_2 line near 118 GHz".[2] NOAA hopes to fly its own improved "Microwave Temperature Sounder", using the same frequency band, on future missions "merged" with the Air Force, starting in about 2005.

Will Proposed Unlicensed 60 GHz Devices Interfere with Satellites?
Consider a satellite orbiting above the earth's atmosphere, its receiving antenna pointed straight down, viewing both the oxygen emission [signal] and scattered signals from terrestrial transmitters [noise]:



1. Information on DMSP was provided by Dr. Niel Baker of Aerospace Corp., on June 20, 1994.
2. McGinnis, D.F., "Protection of Passive Sensors in the 60.4 - 61.2 GHz Band," NOAA document provided by its author, who is Frequency Manager with the National Environment Satellite, Data, and Information Service, NOAA, Department of Commerce.

The “Signal” received from oxygen emission will be, independent of the height or antenna gain of the satellite:[3]

$$Psignal = k \cdot Tant \cdot B$$

Where: *k*=Boltzmann's constant
Tant=Effective Antenna Temperature
B= Bandwidth of receiver
[Note: *This is the power received by a noiseless receiver*]

The “Noise” received from the densely-packed terrestrial transmitters is:

$$P_{noise} = \left(\frac{Nxmit}{Area}\right) \cdot F \cdot (EIRPav) \cdot (A_{footprint}) \cdot (G_{rcvr}) \cdot \left(\frac{\lambda}{4\pi Z}\right)^2 \cdot (Attenuation)$$

Where:
Pnoise = Power originating from earth transmitters, as received by satellite
Nxmit/Area = Transmitters per unit area on earth
F = Fraction of transmitters operating at the satellite's frequency
EIRPav=Average Effective Isotropic Power per transmitter seen by satellite
Afootprint = Area on Earth's surface viewed by satellite antenna
Grcvr = Satellite Antenna Gain
Attenuation = Atmospheric Attenuation
$(\lambda/4\pi Z)^2$ = Loss due to wave spreading
Z = Altitude of satellite

By geometry, the area viewed by the satellite antenna is inversely proportional to its gain:

$$A_{footprint} = \frac{4\pi Z^2}{G_{rcvr}} ,$$

so that power received by the satellite is independent of its altitude or antenna pattern:

$$P_{noise} = \left(\frac{Nxmit}{Area}\right) \cdot F \cdot (EIRPav) \cdot \frac{\lambda^2}{4\pi} \cdot (Attenuation)$$

Naturally, individual transmitter signals will add incoherently with one another. But only in the case where *ALL* transmitters are pointed directly at the satellite is the *EIRPav* in this equation identical to the average of individual transmitter EIRPs. In practice, signals will be randomly scattered and thus angularly dispersed, greatly reducing the signal available in the satellite's angular field of view. We need to estimate *EIRPav* for this case.

---

3. This assumes that the antenna pattern is narrow enough, and that the antenna is correctly pointed so as to “see” atmospheric emission throughout its field of view.

Estimation of *EIRPav*

In order to determine the relative strengths of *Psignal* and *Pnoise*, we first need to estimate *EIRPav*, the average Effective Isotropically Radiated Power per ground-based transmitter. The obviously worst case is the virtually impossible one where all transmitters are operating at the satellite's sounding frequency [F = 1], all transmitters have the maximum legal EIRP, and all transmitters are aimed at exactly the same point in space - a point through which the satellite will eventually pass. In this limiting case, the EIRP appropriate to our calculation would be equal to the maximum legal EIRP: 10 Watts, for example. But a far more realistic estimate would be obtained by realizing that not all transmitters are operating at the crucial satellite frequency [F<1], that not all transmitters will operate at the maximum legal EIRP, that virtually all transmitters will be pointed to a low azimuth angle, with only some fraction of their power being scattered into the relatively narrow acceptance angle of the satellite's antenna [12 degrees in the case of the "DMSP" satellite].

To make a rough estimate of what the average EIRP per transmitter would be, we assume that the average transmitter radiates Pav =10 mW and that this power is initially directed horizontally, then scattered vertically into a hemispherical pattern, due to various randomly-directed reflecting surfaces on earth. In this case:

$$EIRPav = 2 \cdot Pav$$

where:

> $EIRPav$ =Average Effective Isotropic Power per transmitter seen by satellite
> Pav =Average Power per transmitter ,
> and the factor-of-two results from power being concentrated into a hemispherical radiation pattern

If we further assume, arbitrarily, that half the transmitters are operating at the satellite's sounding frequency, then:

$$F \times EIRPav = 0.5 \times 2 \times 10\ mW = 10\ mW$$

Obviously, there is a great deal of uncertainty in our estimate of how much power might be scattered skyward. The worst case would be of order EIRP=10W per transmitter, the educated guess would be of order EIRP= 10 mW per transmitter. In fact, the scattered power would likely be even less than this lower estimate, because much of the signal will be absorbed, rather than scattered, by objects near the ground, and fewer than 50% of the transmitters may be operating at the satellite's sounding frequency.

Atmospheric Attenuation and Noise

In order to determine the relative strengths of *Psignal* and *Pnoise*, we also need to know the value of atmospheric attenuation involved, and the effective antenna temperature due to emission from atmospheric oxygen. To determine these numbers, we contacted a leading authority in the field, Dr. Hans Liebe of the Institute for Telecommunications Science, U.S. Department of Commerce, NTIA. Dr. Liebe, at our request, performed a computer simulation to determine the effective noise temperature of a spaceborne antenna pointed toward earth, and the atmospheric attenuation encountered by a signal travelling from the earth's surface to that spaceborne antenna.[4] The cases of sea level, 5000 feet, and 10,000 feet altitude were simulated.

Pertinent results of Dr. Liebe's simulation are tabulated below:

Table 1: Brightness Temperature[a]

Frequency	*Tant*
60.4 GHz	228 K
60.8 GHz	216 K
61.15 GHz	224 K

a. For an ideal antenna,
Tant = Tbrightness

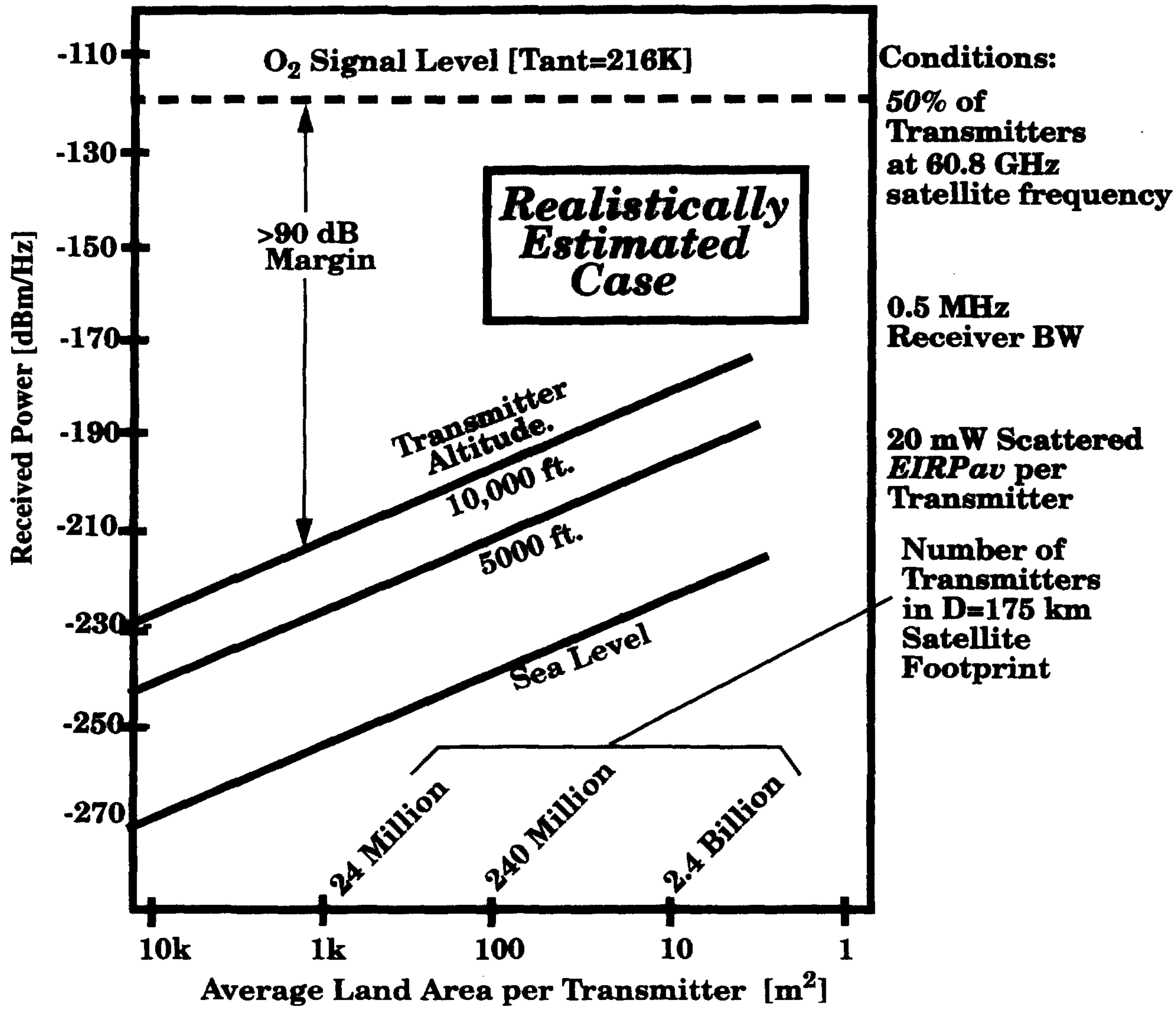
Table 2: Atmospheric Attenuation, Earth-to-Space

Frequency	Altitude	Attenuation
60.4 GHz	sea level	231 dB
60.8 GHz	sea level	162 dB
61.15 GHz	sea level	188 dB
60.4 GHz	5000 ft	201 dB
60.8 GHz	5000 ft	132 dB
61.15 GHz	5000 ft	158 dB
60.4 GHz	10,000 ft	187 dB
60.8 GHz	10,000 ft	118 dB
61.15 GHz	10,000 ft	144 dB

4. H.J. Liebe, private communication, June 15, 1994. A photocopy of Dr. Liebe's summary page is attached to this appendix.

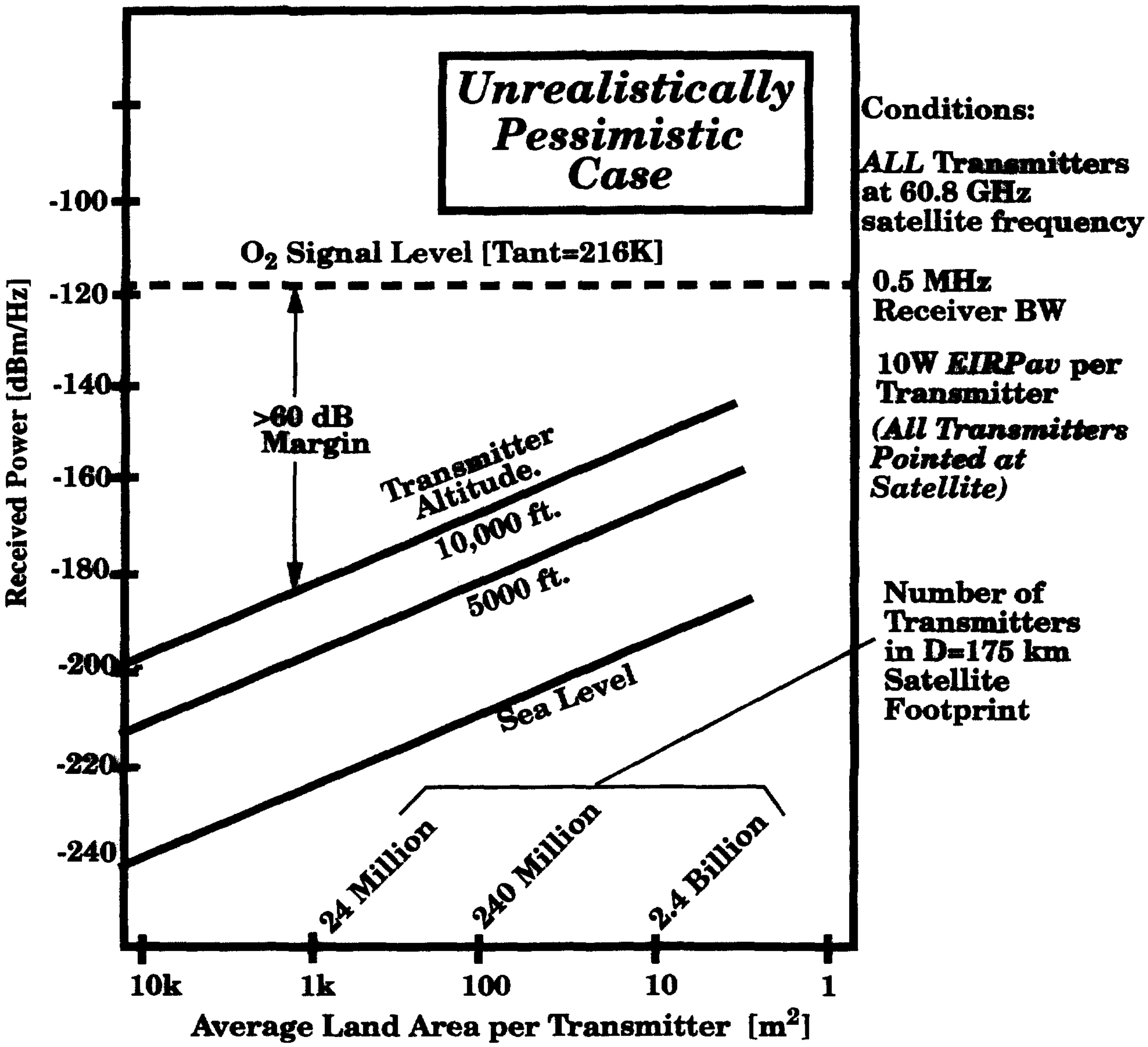
Using these data, we can compute *Psignal* and *Pnoise* for any assumed bandwidth, frequency, and power per unit area resulting from terrestrial transmitters. Since NOAA is interested in a band centered at 60.8 GHz, we choose that frequency. We further assume that the receiver bandwidth is 0.5MHz - the minimum bandwidth quoted to us by NOAA.[5] We assume $F \times EIRPav$ = 10 mW per transmitter, as estimated earlier.

We then plot the received signal and noise as a function of transmitters per unit area:



5. McGinnis, pg. 4. Minimum bandwith is the worst case here, since the noise-like oxygen emission signal increases in strength as bandwidth increases.

For the worst conceivable case, where *ALL* transmitters are pointed directly at the satellite, we would have the following result:



Clearly, the margin of safety is huge. We conclude that satellite receivers operating at 60.8 GHz will not possibly be able to receive signals from low-power unlicensed terrestrial transmitters, no matter how many such transmitters may ultimately be deployed. Furthermore, the "noise" contributed by large numbers of transmitters will have a negligible effect on the temperature-measuring resolution of spaceborne instruments, given the huge received power margins presented above.

Hewlett-Packard Company
Laboratories
3500 Deer Creek Rd
Palo Alto, California 94304-1392
P.O. Box 10350, Palo Alto, California, 94303-0867

HEWLETT PACKARD

FAX Reply to:

Rory Van Tuyl
MS 26M-2
(415)857-6711
(415)852-8626 [Fax]
vantuyl@hud.hpl.hp.com

June 7, 1994

11 pages

Dr. Hans Liebe
NTIA/ITS.S3
325 Broadway
Boulder, CO
80303

Dear Dr. Liebe:

As I mentioned on the phone yesterday, we are proposing the use of low-power mmWave communicators for terrestrial use in the band 59-64 GHz. The FCC has heard concern from those officials responsible for the SSMIS satellite and its possible successors about the possibility that terrestrial communicators might interfere with this satellite. We believe there is little likelihood of such interference, and seek authoritative computations to show what the true situation would be.

The satellites in question operate receivers over the range 60.4348 to 61.1506 GHz, with bandwidths ranging from 1.5 MHz to 60 MHz. Future versions are planned at the same frequency, but with bandwidths as low as 0.5 MHz. I do not know any particulars about the satellite's antenna or receiver noise figure.

I propose that there are just two numbers needed with which to make simple calculations of various scenarios involving interference. They are:

1. The line-of-sight attenuation due to the atmosphere from various altitudes to space. For example: a) Sea-level to space; b) 5000 ft. altitude to space; c) 10,000 ft. altitude to space. With these numbers, one could predict the atmospheric loss for any transmitter of practical interest, as it would be viewed from space.
2. The antenna temperature for a 60.43 - 61.15 GHz receiver pointed straight down from a satellite to earth. Alternatively, the power per unit area per unit bandwidth emanating from the earth into space in this frequency range could be used.

With these two numbers - authoritatively quoted by you based on computer simulation - we, or others, could do a variety of simple hand calculations which would be of adequate accuracy to identify whether an interference problem might exist for a given scenario of ground-based transmitters.

In our phone conversation, you indicated that such a simple 1-ray computation could be easily done, but that multiple transmitter problems would be more difficult, and would require some special arrangement with your agency. I think we should take this one step at a time, starting with the simple case outlined above.

Thank you in advance for your help. Having an authoritative source for this important information is of great importance to us, and I know of no better authority on the subject.

Best Regards,

Rory Van Tuyl

Rory Van Tuyl

h_0-to-space (zenith path)

$h_0 = 0$ km

AZ = .0 EL = 90.00

FREQ(GHz)	SC(dB)	TB-SC
60.2000	190.761	285.774 K
60.3000	252.351	285.781
60.4000	230.830	285.787
60.5000	205.072	285.792
60.6000	179.169	285.794
60.7000	167.054	285.797
60.8000	161.600	285.798
60.9000	161.464	285.797
61.0000	167.633	285.796
61.1000	188.273	285.793
61.2000	187.824	285.789
61.3000	164.653	285.784
61.4000	155.883	285.776

0.5 km

$h_0 = 1.5$ km (5000')

EL = 90.00

SC(dB)	TB-SC
161.091	272.665 K
222.534	272.673
200.892	272.678
175.042	272.682
149.076	272.683
136.925	272.683
131.462	272.681
131.341	272.678
137.551	272.674
158.256	272.669
157.899	272.662
134.847	272.655
126.227	272.645

$h_0 = 3$ km (10000')

EL = 90.00

SC(dB)	TB-SC
147.280	266.101 K
208.653	266.111
186.960	266.116
161.079	266.118
135.100	266.117
122.953	266.113
117.505	266.109
117.411	266.103
123.655	266.096
144.404	266.088
144.100	266.081
121.113	266.071
112.569	266.059

3.5 km

straight-down

$h_\infty = 130$ km

AZ = .0 EL = -90.00

FREQ(GHz)	SC(dB)	TB-SC
60.2000	190.761	220.146 K
60.3000	252.351	250.861
60.4000	230.830	228.094
60.5000	205.072	222.723
60.6000	179.169	218.434
60.7000	167.054	217.244
60.8000	161.600	216.920
60.9000	161.464	217.219
61.0000	167.633	218.048
61.1000	188.273	223.912
61.2000	187.824	224.134
61.3000	164.653	218.063
61.4000	155.883	217.221

Dr. HANS J. LIEBE
Senior Research Engineer
Institute for Telecommunication Sciences
U.S. Department of Commerce
NTIA / ITS.S4 3
325 Broadway
Boulder, Colorado 80303-3328
(303) 497-3310
FTS 320-3310
FAX (303) 497-5993
Private (303) 494-1053

6-15-94

H. Liebe

A1

Appendix C:

Measurement Considerations for the mmWave Bands

Power Measurement Distance

Millimeter Wave antennas can produce patterns with a wide variety of far-field distances, where R, the far-field distance is conventionally taken as:[1]

$$R = \frac{2D^2}{\lambda}, \quad \text{or......} \quad \left(\frac{R}{\lambda}\right) = 2\left(\frac{D}{\lambda}\right)^2$$

And: D= Height or diameter of antenna aperture
λ = wavelength

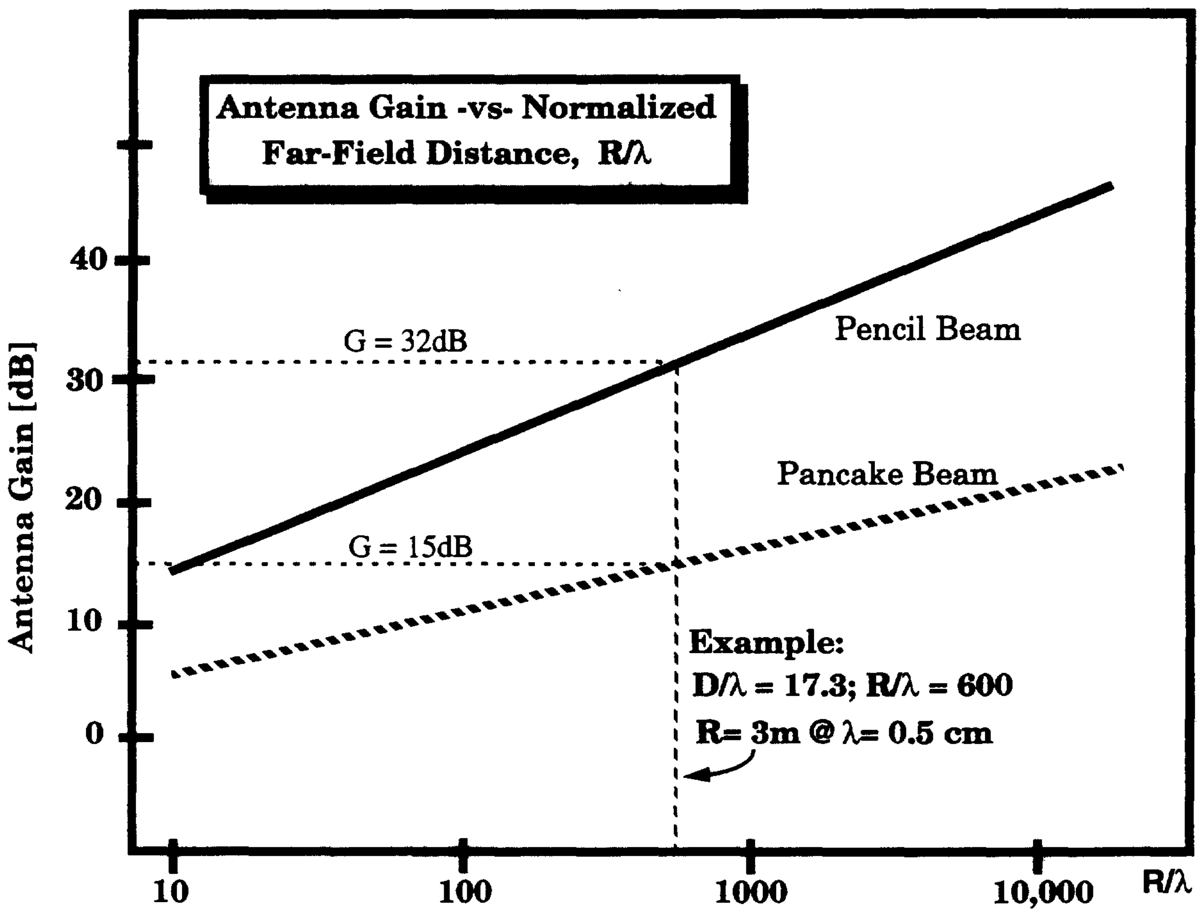
Similarly, antenna gains can be expressed in terms of D/λ:

$$Gpencil = 5.4\left(\frac{D}{\lambda}\right)^2 \qquad Gpancake = 1.9\left(\frac{D}{\lambda}\right)$$

For a typical "pencil" beam, such as that from a parabolic reflector

For a typical "pancake" beam, a flat disc-shaped radiation pattern

Using these relations, we can plot the gain -vs- far-field distance for these representative beam shapes:



1. Johnson, R., "Antenna Engineering Handbook," pg. 1-11.

From the above, we can see that:

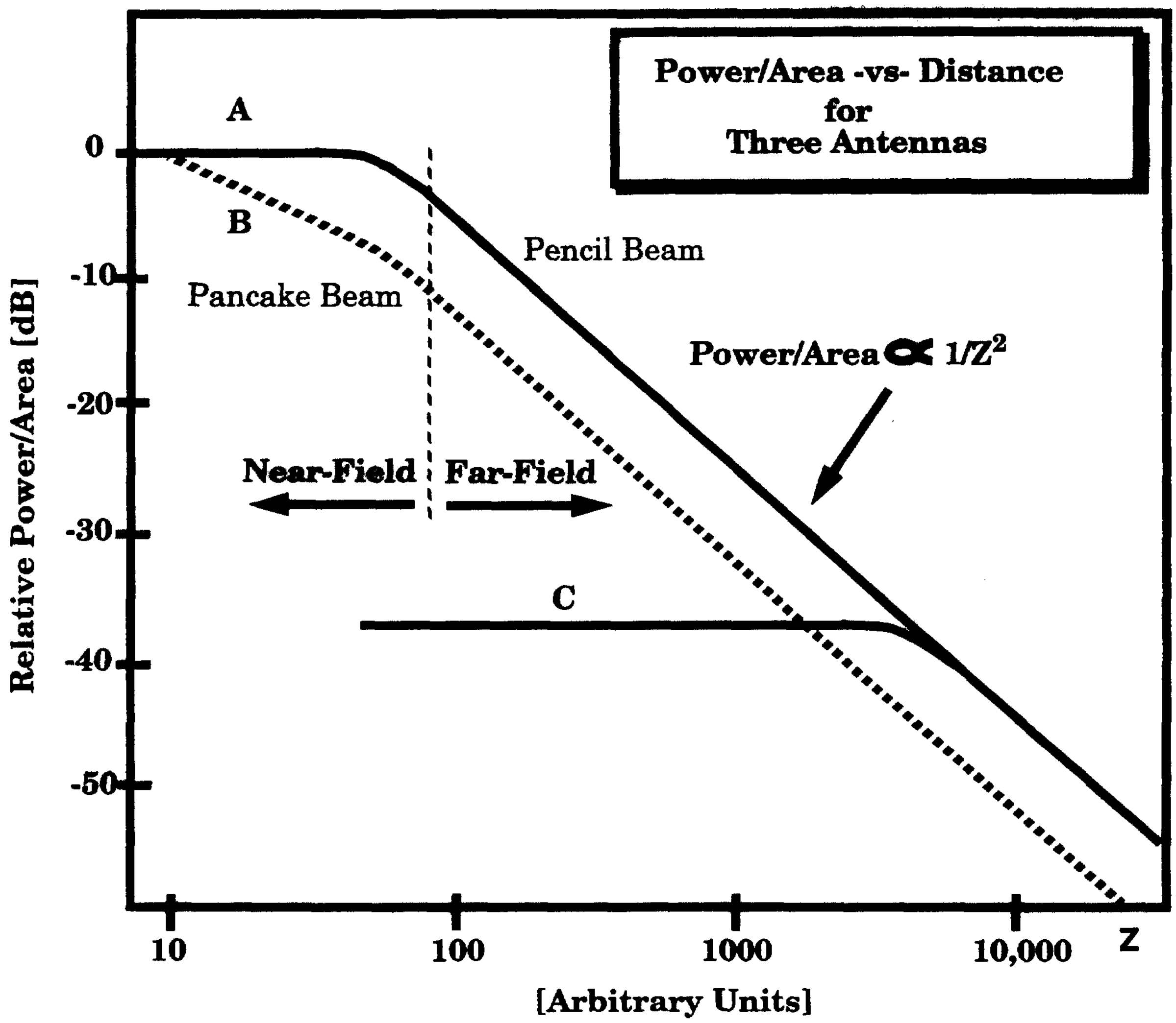
A. Depending on frequency of operation and details of design, far-field distances may be less than 3 meters, equal to 3 meters, or greater than 3 meters for practical mmWave antennas.

B. Antenna gain, hence EIRP, can differ widely between antennas of similar size. For example, a pencil beam antenna will have 17dB more gain - thus correspondingly higher EIRP - than a pancake beam antenna of similar dimensions .

Therefore, if 3 meters were to be chosen as the standard measurement distance, we would need to know the antenna gain and/or its pattern in order to deduce important power limits from our measurements.

Why Does It Matter?

If we want to observe the worst-case power density, for purposes of safety compliance, we need to know the power in the near field, preferably as close as possible to the radiator. If, on the other hand, we want to know the Effective Isotropically Radiated Power [EIRP], for purposes of estimating transmitter range, we need to measure in the far field.



From the above plot, we see that Antennas A and B have similar far-field distances, with the pancake beam, B, having less EIRP, hence less range. However, because the near-field behavior of A and B is entirely different, we see that these two antennas, which have different EIRPs, have similar power densities close to the antenna. Nothing can be inferred about this close-in power density from a far-field measurement without additional information about the antenna pattern.

On the other hand, when measured at very great distances, antennas A and C - both pencil-beam radiators - have equal power densities, hence their EIRPs are identical. But a measurement made at Z=1000, for instance - in the far field of A and the near field of B - would show very different power densities, and might lead to the conclusion that the higher-gain antenna C would have less range than antenna A, which is not the case.

Therefore, it is really necessary to know something about the beam pattern of mmWave antennas if proper conclusions are to be drawn from power measurements

Waveguide Bands

Some important standard waveguide bands for the frequencies of interest are:

Table 1: Waveguide Bands

Designation	Frequency
Q	33-50 GHz
U	40-60 GHz
V	50-75 GHz
E	60-90 GHz
W	75-110 GHz
F	90-140 GHz
D	110-170 GHz
G	140-220 GHz

Set "A"

Set "B"

Most measurement equipment will couple to free space through standard hardware available for these bands. However, not all equipment is available in all these bands [see below]. Note that the frequencies of interest [40 - 170 GHz] can most efficiently be covered with 4 waveguide bands - either Set "A" or Set "B". Many instruments make use of a set of interchangeable sensors, one for each available waveguide band. Until such time as services are implemented in the higher mmWave frequencies, measurements to 110 GHz would be sufficient, in which case only three waveguide bands [Q, V, W] would be necessary.

Power Measuring Equipment

Following is a list of some commercially available measurement equipment for the mmWave bands above 40 GHz. This list is provided for information only - no recommendations are implied.

A. For basic power measurements in free space, a broadband acousto-optic power meter has been used by plasma researchers and other laboratory workers. This technique has the advantage of freedom from frequency-dependent coupling to the wave under test throughout the mmWave spectrum, but does require a 40 Hz beam chopper to operate. Such meters are accepted as measurement standards in the U.K., and are commercially available.[2] Sensitivity is of the order of -30dBm.

B. For waveguide-band power measurements with greatest convenience, but less accuracy, power meters are available in standard waveguide bands, but only to 140 GHz.[3] Sensitivity is of the order of -30 dBm. All power meter measurements, of course, contain an element of error due to the uncertainty as to how much power is actually coupled into the sensing element.

C. Waveguide band detectors are available for use with video detection instruments, such as meters, scalar network analyzers, and antenna pattern measurement systems.[4] Sensitivity is on the order of -53 to -36 dBm.

D. For frequency-selective measurements, broadband RF spectrum analyzers are available to 50 GHz, and should be very useful for the lower frequency bands.[5] However, frequency-dependent reflections from the instrument, when combined with various input coupling arrangements [horns, adaptors, etc.] can introduce calibration errors.

E. Because equipment to be type-certified will be narrowband, and because free-space coupling tends to be through standard waveguide hardware, most frequency-selective measurements can conveniently be made with waveguide band harmonic mixers interfaced to a spectrum analyzer.[6] This is the recommended method for general and out-of-band spurious response testing. However, these spectrum analyzers are not preselected, so measurements require careful interpretation.[7] Sensitivities vary with waveguide band, from -104 dBm to -60 dBm [170 GHz].

---

2. Thos. Keating Ltd., Billinghurst, West Sussex, England. [PC-based Power Meter for Far-Infrared and mmWaves].
3. Anritsu MP715A, MP716A, MP717A, MP81B, MP82B.
4. Millitech DXW series detectors.
5. Hewlett Packard HP8565E.
6. Tektronix WM780 series or Hewlett Packard 11970 series harmonic mixers operate with commercial spectrum analyzers and are available from 40 GHz to 170 GHz. Millitech MXW series mixers offer greater sensitivity but less convenience for measurements above 75 GHz.
7. Preselected downconverting mixers are available only to 75 GHz [HP 11974 series].

HEWLETT-PACKARD CO.

Rory L. Van Tuyl
Hewlett-Packard Laboratories
3500 Deer Creek Rd.
Palo Alto, CA
94304-1392

January 29, 1995

Rory Van Tuyl

Rory Van Tuyl